Measurements of aerosol optical properties at a suburban site in Belgium

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1 INTRODUCTION

The Royal Meteorological Institute of Belgium has several instruments at its disposal that are able to measure aerosol optical properties simultaneously. The instruments are located at Uccle, Belgium (50°48'N, 4°21'E, 100m asl), a residential suburb of Brussels about 100km from the shore of the North Sea. The dataset consists of aethalometer, nephelometer and Brewer spectrophotometer measurements, collected over a period from January 2015 to June 2017. A detailed analysis of the data was performed and the results of this analysis will be presented.

2 INSTRUMENTS

2.1 *Brewer spectrophotometer (#178; Kipp&Zonen)*

- Measurements: 2001 - present
- Originally designed to measure ozone in the atmosphere from UVB radiation
- Can also be used to retrieve the Aerosol Optical Depth (AOD) in the UVB region from
  1. direct sun measurements => AOD at 303.3, 310.1, 313.5, 316.8 and 320.1nm (Cheymol and De Backer, 2003)
  2. sun scan measurements => AOD at 340nm (De Bock et al. 2010)

2.2 *Aethalometer (AE31; Magee Sci., 7 wavelengths)*

- Measurements: May 2013 - present (every 5 min)
- Measures the light absorption of aerosol particles at wavelengths covering the UVA and the Near InfraRed (370, 470, 520, 590, 660, 880 and 950nm)
- The absorption coefficient (σ_a) (in Mm^{-1}) and the mass concentration (in ng/m^3) of light-absorbing particles can be derived from the instrument (Weingartner et al. 2003).
- The Absorption Angström Exponent (AAE) is calculated as follows: $AAE_{370/880} = -[ln(\sigma_{a_{370}}) - ln(\sigma_{a_{880}})]/[ln(370) - ln(880)]$

2.3 *Nephelometer (3563; TSI)*

- Measurements: selected periods between March 2015 - July 2017 (every min)
- Measures the scattering(σ_s) and backscattering coefficient (σ_{bs}) (in Mm^{-1}) of particles at 450, 550 and 700nm

The Single Scattering Albedo (SSA) can be determined by combining the absorption measurements of the aethalometer and the scattering measurements of the nephelometer: $SSA = \sigma_s/(\sigma_s + \sigma_a)$

In addition, data from the Belgian Interregional Environment Agency (IRCEL-CELINE) has been used to check the relation with PM_{10} and $PM_{2.5}$ measurements and the occurrence of smog days.

3 RESULTS

For 28 days between January 2015 and July 2017, simultaneous measurements (max. time difference of 5 minutes) of aerosol optical properties have been analyzed. The following relations have been analyzed for the study period:

- σ_s at 450, 550 and 700nm versus AOD (Figure 1)
- σ_a at 470, 520 and 660nm versus AOD (Figure 2)
- SSA versus AOD (Figure 3)
- AAE versus AOD (Figure 4)

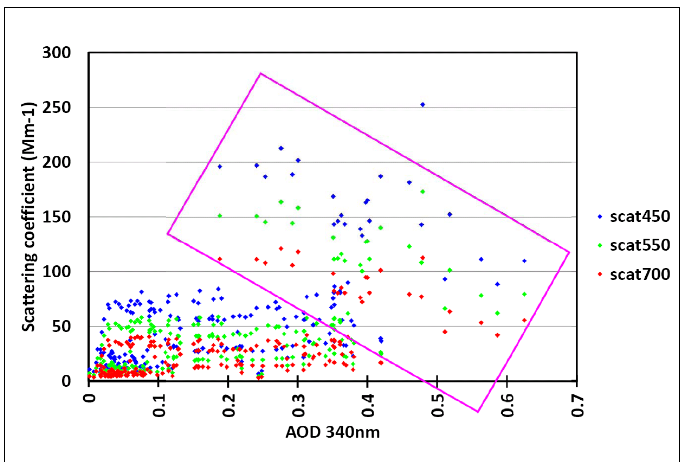

Figure 1. Nephelometer measurements of σ_s versus Brewer AOD measurements.

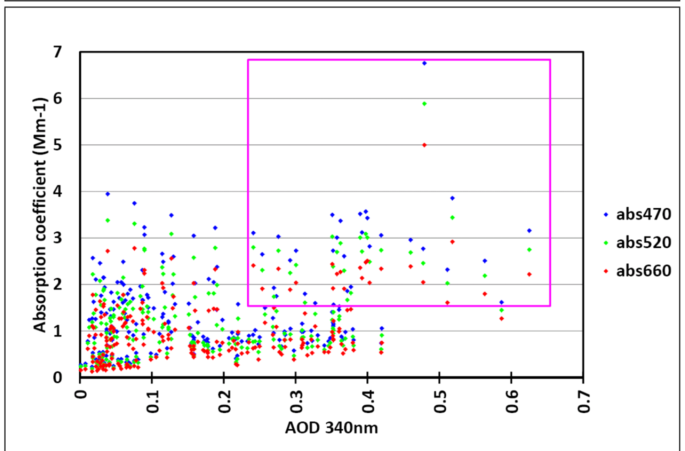

Figure 2. Aethalometer measurements of σ_a versus Brewer AOD measurements.

In both figure 1 and 2, there is a group of data (in the magenta rectangle) which clearly stands out against the other data points. This group of data points is characterized by higher AOD, scattering and absorption coefficients. These points represent the data from the following days, which will be referred to as smog days from here on.

- Sunday 17/03/2015
- Friday 11/03/2016
- Saturday 12/03/2016
- Friday 26/08/2016
- Monday 13/03/2017
- Thursday 16/03/2017

The smog days are also characterized by higher PM amounts (higher than $50\mu g/m^3$) and higher Black Carbon (BC) mass concentration values (according to measurements from www.irceline.be).

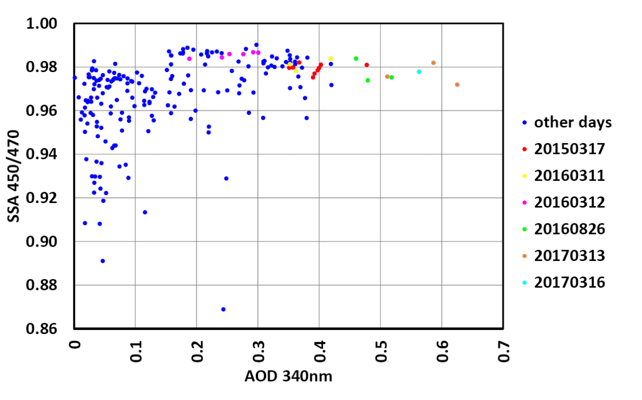

Figure 3. SSA values (derived from $\sigma_{a_{470}}$ and $\sigma_{s_{450}}$ from the aethalometer and nephelometer) versus Brewer AOD measurements. Each smog day is represented in a certain color, whereas the non-smog days are shown in blue.

Figure 3 shows that the SSA values for the smog days range from 0.97 to 1.00 and do not differ significantly from the other values.

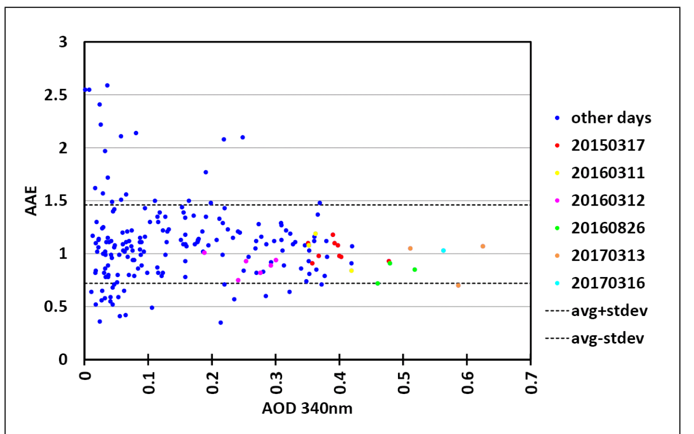

Figure 4. $AAE_{370/880}$ versus Brewer AOD measurements. Each smog day is represented in a certain color, whereas the non-smog days are shown in blue.

The AAE is known to be linked to the composition of the aerosol mixture. AAE values around 1 are consistent with the presence of fresh soot particles (traffic). AAE values distinctly larger than 1 are indicative of the presence of other organic compounds, absorbing stronger towards the UV (e.g., from wood burning). Figure 4 shows that for smog days, the AAE are within 1 standard deviation of the average AAE and they are all close to 1.

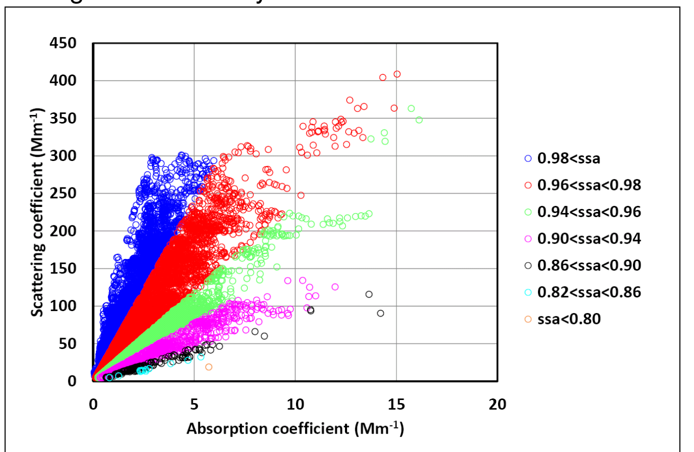

Figure 5. $\sigma_{s_{470}}$ versus $\sigma_{a_{450}}$ for all simultaneous measurements at Uccle. The different colors represent different SSA values.

Figure 5 shows that there are clearly different types of aerosol mixtures present at Uccle. High σ_s values are not always accompanied by high σ_a values. Also, a certain SSA value can be the result of different combinations of σ_s and σ_a. Future research might relate the different combinations of σ_s and σ_a to different air masses.

4 CONCLUSIONS

Analyzing AOD and aerosol scattering and absorption properties at several wavelengths, offers an insight into the dominant aerosol size and the aerosol type in suburban Brussels. The dataset of optical aerosol data covers only a limited time period until now, but we can already see some interesting features.

Smog days clearly distinguish themselves from normal days: The AOD, BC mass concentration, σ_a and σ_s are all elevated. The AAE is around 1, i.e. the absorbing aerosol population is dominated by traffic-related, fresh soot particles. The SSA does not significantly differ from normal days, i.e. particle types which are optically light are clearly dominating, which suggests that secondary aerosol formation plays a dominant role in sub-urban Brussel smog days.

The relation between AOD and σ_s, σ_a, SSA and AAE is not straightforward. For the same AOD value, a significant spread in σ_s and σ_a values could be observed. For SSA and AAE the spread in the values increases towards lower AOD values.

References

- Cheymol, A. and De Backer, H. (2003), J. Geophys. Res., 108 (D24), 4800
- Weingartner, E., Saathoff, H., Schnaiter, M., Streit, N., Bitnar, B. and Baltensperger, U. (2003), J. Aero. Sci., 34, 1445-1463
- De Bock, V., De Backer, H., Mangold, A. and Delcloo, A. (2010), Atmos. Meas. Tech., 3, 1577-1588

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